Spatial and temporal variations in the trapped terrestrial vertebrate fauna of the Hamersley Range, Western Australia

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Abstract

Fifty-four sites were surveyed in the Hamersley Range in March and November 2008 to assess temporal and spatial variability of terrestrial vertebrates and to compare this assemblage with published data for the Abydos Plain, an area to the north-east but still within the Pilbara bioregion. Appreciable seasonal variations in the trapped fauna were evident on the Abydos Plain and the Hamersley Range. Results indicate that single season surveys, and surveys that catch relatively few individuals, do not provide an adequate appreciation of the trappable fauna assemblages in the Pilbara. Similar to the Abydos Plain results, the vertebrate fauna assemblages in creek lines and the valley floor of gorges were different from that on flat plains and gently undulating areas, and in the Hamersley Range, the fauna assemblage was also different on rocky sloping terrain. Higher maximum daily temperatures in March compared with November seemed to be the main reason for a significantly higher number of individuals being caught, from which we concluded that surveys undertaken in the Pilbara during the cooler months would only record a proportion of the trappable vertebrate fauna in the area.

Keywords: Western Australia, Pilbara, fauna survey, trapping

Introduction

Temporal variation in the trapped terrestrial vertebrate fauna assemblage are apparent in many arid and temperate areas of Western Australia (How & Cooper 2002; Cowan & How 2004; Thompson & Thompson 2005), but there is a paucity of published information on temporal variations in the trappable fauna assemblages for the Pilbara, inland sandy deserts and the Kimberley. The only published data on temporal variations in fauna assemblages for the Pilbara are based on a Western Australian Museum survey in the late 1980s and early 1990s on the Abydos Plain which is to the north-east of the Hamersley Range. In the Abydos Plain study, How and Cooper (2002) reported that captures for the saxicoline rodent, *Zyzomys argurus*, showed little fluctuation over three years compared with *Pseudomys hermannsburgensis* and *Mus musculus* and How and Dell (2004) reported marked seasonal variation in the reptile assemblage during this same period. Both How and Cooper (2002) and How and Dell (2004) commented that fire had a significant effect on the relative abundance of mammals and reptiles living in *Triodia* habitats.

Vegetation and soil patterns normally have a marked influence on the spatial distribution of vertebrates at a local scale (How & Cooper 2002; Thompson *et al*. 2003; How & Dell 2004; Thompson & Thompson 2008; Gibson & McKenzie 2009). For example, Thompson *et al*. (2003) showed appreciable variation in the trapped reptile assemblage in 12 closely located habitats on the sand plain at Bungalbin, Western Australia. How and Cooper (2002) and How and Dell (2004) recorded marked differences in the mammal and reptile fauna assemblages based on soils and vegetation patterns on the Abydos Plain in the Pilbara and Gibson and McKenzie (2009) reported patterns of small mammal distribution in the Pilbara were mostly influenced by the substrate. Based on these data we anticipated both temporal and spatial variability in the trapped vertebrate fauna in the Hamersley Range.

Our objective here was to compare species richness between the Hamersley Range and the survey results for the Abydos Plain (How & Cooper 2002; How & Dell 2004) and to examine the extent of temporal and spatial variation in the trapped vertebrate fauna in the Hamersley Range.

The Abydos Plain survey is located in the Pilbara 1 (PIL1 – Chichester) IBRA subregion, which Kendrick and McKenzie (2001) described as undulating Archaean granite and basalt plains. The area is a relatively flat, stony plain drained by the Yule, Turner and De Grey Rivers and their tributaries (Figure 1). This bioregion is

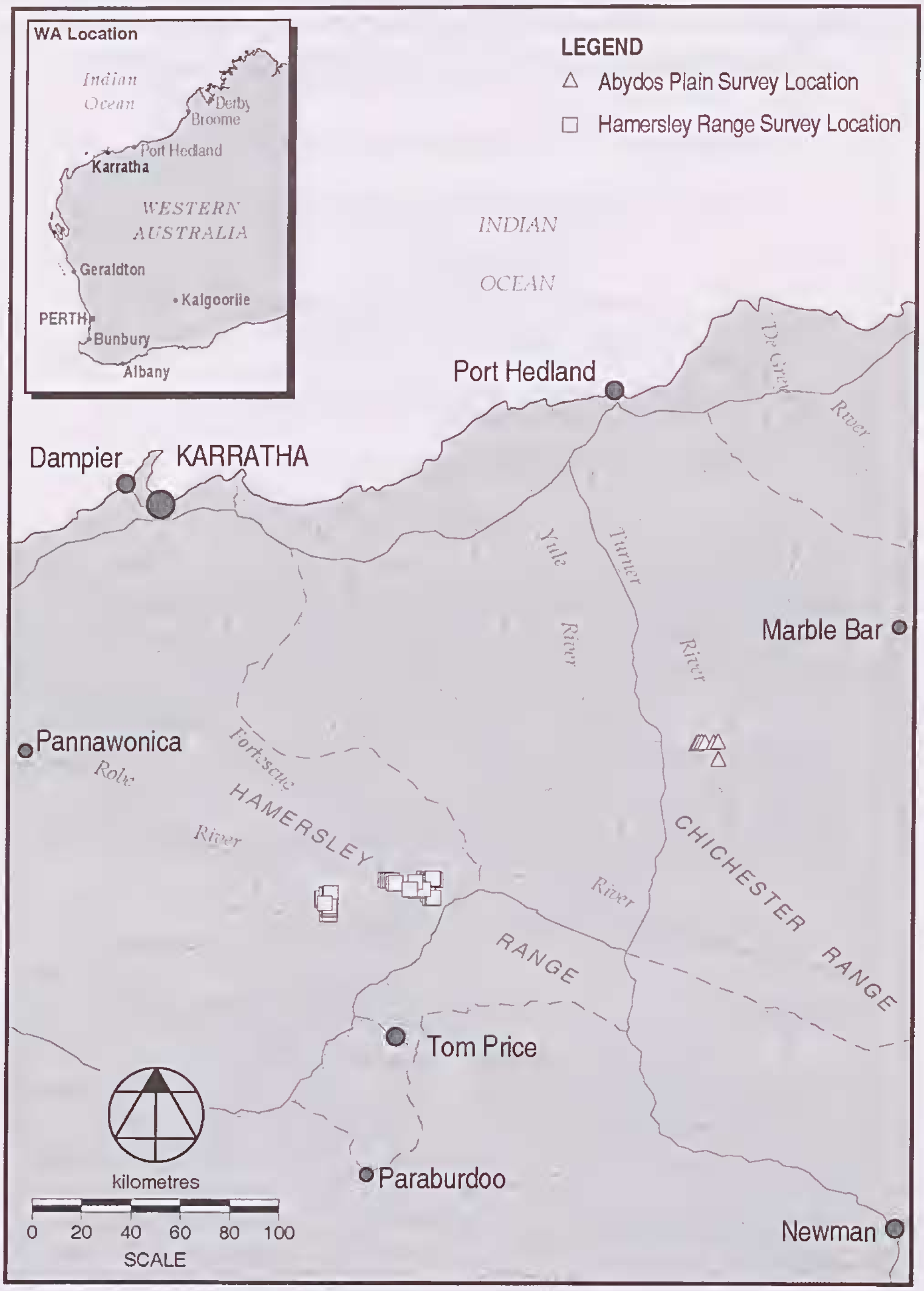

Figure 1. Survey sites in the Hamersley Range and the Abydos Plain.

mostly vegetated with spinifex and scattered acacia and eucalypt woodlands, with more dense vegetation along drainage lines. How and Cooper (2002) and How and Dell (2004) sampled eight sites over nine periods (March 1988, May 1988, September 1988, February 1989, April 1989, September 1989, March 1990, July 1990 and October 1990) using drift fences to direct fauna into PVC pipe or conical shaped pit traps. Type A and B aluminium box traps (Elliott design) were also set at each trapping site and baited with universal bait. Pit traps were open for 58 days of the 74 days over which trapping occurred.

Our Hamersley Range survey sites are located in the Pilbara 3 (PIL3 – Hamersley) IBRA subregion. Kendrick (2001) described this bioregion as a mountainous area of Proterozoic sedimentary range and plateaux dissected by gorges, which are vegetated with low mulga woodland over bunch grasses on fine textured soils in the valley floors. Fauna habitats that we surveyed included rocky substrate vegetated with spinifex, often with scattered trees and shrubs of varying densities, either on a flat, undulating or sloping terrain, with a mixture of bunch grasses and spinifex on loamy soils in flat or undulating areas, and ephemeral creek beds that supported a denser community of shrubs and trees. The latter category is mostly located in broad gorges, some with steep-sided hills or rocky faces. A number of survey sites contained vegetation that had been partially degraded by cattle.

Climate

The climate for this region is semi-desert, with most of the rain coming in summer from cyclonic events and thunderstorms. Figures 2 and 3 show the mean monthly average maximum and minimum temperatures and rainfall for Tom Price, which is about 60 km south of our Hamersley Range survey sites and Redmont which is about 20 km south of the Abydos Plain survey sites. Average maximum daily temperatures from December to February are in the high 30s to 40 °C dropping to the mid 20s in winter, with mean temperatures at Redmont being a couple of degrees higher than at Tom Price. Minimum daily average temperatures are typically 15 °C lower than the maximum temperatures. The rainfall patterns at these two weather stations were similar with most rain occurring between January and March, but Tom Price generally receives more rain during summer than Redmont (Figures 2 and 3).

Daily minimum ($F_{1,29}$= 18.1, P < 0.01) and maximum ($F_{1,31}$= 98.2, P < 0.01) temperatures at Tom Price, the nearest weather station to our survey sites, were significantly higher during our March survey (19.8 °C and 37.4 °C respectively) than during our November survey (16.4 °C and 33.9 °C respectively). It rained on two of the 14 survey days during March (12.4 and 0.4 mm respectively) and there was no rain during the November survey.

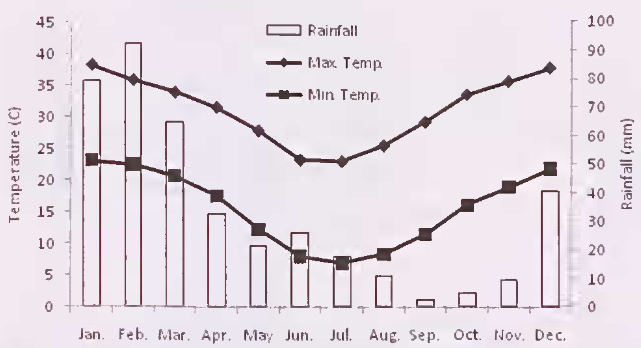

Figure 2. Monthly maximum and minimum temperatures and rainfall averages for Tom Price.

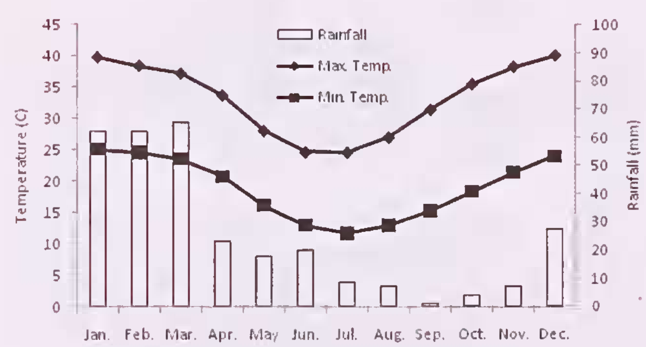

Figure 3. Monthly maximum and minimum temperatures and rainfall averages for Redmont.

How and Cooper (2002) reported significant seasonal and annual variations in rainfall at the Woodstock Station, but did not provide data on temperature or rainfall during their surveys periods.

Methods

Survey sites and trapping protocols

Fifty-four sites were sampled in the Hamersley Range, approximately 60 km north of Tom Price, Western Australia (Figure 1). Our analysis only addressed the trappable vertebrate assemblage, excluding any amphibians that were caught during the survey, as their capture was significantly influenced by the two rainfall events in March. Juveniles were identified when they were caught based on the known size of adults.

Trapping was undertaken in March 2008 and again in November 2008, with all traps being left open for seven days and nights for each survey. All traps were dug in during February/March 2008 and immediately closed until the set up program was completed. Each survey site contained four trap lines. Each trap line contained three 20 L PVC buckets, three 150 mm by 500 mm deep PVC pipes as pit-traps and three pair of funnel traps evenly spaced along a 30 m fly-wire drift fence (250 mm high; Figure 4). In addition, three aluminium box traps (two small; 330 X 100 X 90 mm and one large; 380 X 120 X 110 mm) were set adjacent to each drift fence. Aluminium box traps were baited with a mixture of sardines, rolled oats and peanut butter. Trap lines were arranged either parallel to each other, or end-on, depending on the availability of habitat and site access restrictions. For example, in some creek lines each trap line was located end-on 50–80 m apart and ran parallel to the direction of water flow to ensure that all traps were within a relatively homogenous habitat type. Buckets used as pit-traps contained two sheets of polystyrene in the bottom, funnel traps were covered with two shade covers and aluminium box traps were placed under bushes or covered with a shade cover to protect caught individuals from solar radiation.

For each survey site the combined trapping effort for March and November was 840 trap-nights (*i.e.* 168 bucket trap-nights, 168 pipe trap-nights, 168 aluminium box trap-nights and 336 funnel trap-nights) to give a total of 45,360 trap-nights of survey data. Almost all animals caught were identified and then immediately released near where they were caught, but far enough away from

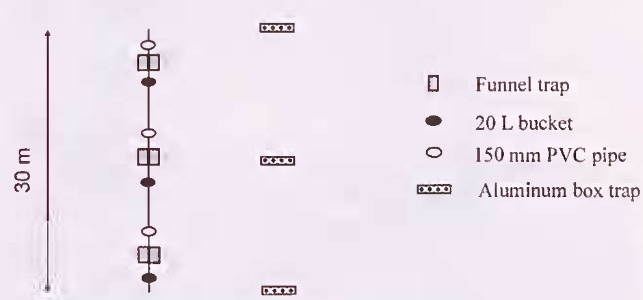

Figure 4. Trapping layout for each trap line.

Table 1

Percentage of individuals (shown as a decimal) caught for each species of the total number per cluster as shown in Figure 5 with the total number of individuals and species for each family

Family	Species	Clusters as shown in Figure 5							
		A	B	C	D	E	F	G	Total
Dasuridae	*Dasykaluta rosamondae*					0.15	0.44		
	Dasyurus hallucatus	0.20	0.03						
	Ningaui timealeyi	0.61		2.33	4.00	0.75	0.79	1.12	
	Planigale spp.	3.24	0.47	18.60		4.48	3.02	2.25	
	Sminthopsis macroura	1.21	0.16			5.83	2.14	5.62	
	# Individuals	26	21	18	1	75	233	8	382
	# Species	4	4	2	1	4	4	3	5
Muridae	*Mus musculus*					0.30	0.36	2.25	
	Pseudomys desertor	1.42	0.31	1.16		2.84	5.32		
	Pseudomys hermannsburgensis	1.62	0.31	6.98		2.99	6.33		
	Zyzomys argurus	0.20	0.03	1.16	4.00	0.15	0.05		
	# Individuals	16	21	8	1	42	440	2	530
	# Species	3	3	3	1	4	4	1	4
Agamidae	*Amphibolurus longirostris*		0.19			1.35	1.62	14.61	
	Ctenophorus caudicinctus	6.88	0.22	5.81	4.00	5.83	1.23	1.12	
	Ctenophorus isolepis					0.15	2.36		
	Pogona minor	0.81	0.06	2.33		0.45	1.10		
	# Individuals	38	15	7	1	52	230	14	357
	# Species	2	3	2	1	4	4	2	4
Boidae	*Antaresia perthensis*						0.05		
	Antaresia stimsoni	0.20	0.25			0.45	0.47	1.12	
	# Individuals	1	8	0	0	3	19	1	32
	# Species	1	1	0	0	1	2	1	2
Elapidae	*Brachyurophis approximans*	2.23	0.37		4.00	0.60	0.38	1.12	
	Demansia psammophis	0.40				0.15	0.08		
	Demansia rufescens	0.40	0.03			0.30	0.25	1.12	
	Furina ornata	0.20	0.09			0.15	0.16		
	Parasuta monachus		0.03				0.14		
	Pseudechis australis	0.40				0.30	0.41		
	Pseudonaja modesta	0.40					0.16		
	Pseudonaja nuchalis		0.16				0.19		
	Suta fasciata			1.16			0.11		
	Vermicella snelli	0.40					0.03		
	# Individuals	22	22	1	1	10	70	2	128
	# Species	7	5	1	1	5	10	2	10
Gekkonidae	*Diplodactylus conspicillatus*					0.75	6.14		
	Diplodactylus jeanae	0.20					0.00		
	Diplodactylus savagei				4.00		0.03		
	Gehyra pilbara	0.40				0.15	0.03		
	Gehyra punctata	0.40				0.15	0.03		
	Gehyra variegata	0.40	0.19	1.16		0.15	0.44	3.37	
	Heteronotia binoei	10.93	0.37	1.16	8.00	5.98	2.93	5.62	
	Lucasium stenodactylus					0.15	0.11		
	Lucasium wombeyi	4.25	0.09		4.00	1.20	0.63		
	Nephrurus milii		0.03						
	Nephrurus wheeleri		0.03	2.33			0.36		
	Oedura marmorata		0.03						
	Strophurus elderi						0.11		
	Strophurus jeanae	0.20					0.69		
	Strophurus strophurus						0.05		
	Strophurus wellingtonae	0.61				0.15	0.71		
	# Individuals	86	24	4	4	58	447	8	631
	# Species	8	6	3	3	8	13	2	16

Table 1 (cont.)

Family	Species	Clusters as shown in Figure 5							
		A	B	C	D	E	F	G	Total
Pygopodidae	*Delma elegans*	0.20	0.03				0.03		
	Delma nasuta	0.20	0.09		4.00		0.08		
	Delma pax	1.01	0.06			0.60	0.38	1.12	
	Delma tincta						0.03		
	Lialis burtonis	1.21	0.03			0.30	0.36		
	Pygopus nigriceps	0.20	0.03			0.15	0.27		
	# Individuals	14	8	0	1	7	42	1	73
	# Species	5	5	0	1	5	6	1	6
Scincidae	*Carlia munda*	2.63	1.37			3.44	5.95	44.94	
	Carlia triacantha			2.33		0.15	3.56		
	Ctenotus duricola	6.88	0.03	8.14		12.11	2.49		
	Ctenotus grandis	1.01	0.62			1.94	6.66	2.25	
	Ctenotus helenae	1.62	0.72			11.81	13.19	5.62	
	Ctenotus leonhardii	0.40		2.33			0.38		
	Ctenotus nigrilineatus						0.08		
	Ctenotus pantherinus	10.93	0.44	9.30		12.86	6.61		
	Ctenotus rutilans	0.20					0.03		
	Ctenotus saxatilis	18.83	2.37	5.81	36.00	3.29	3.34		
	Ctenotus serventyi						0.03		
	Cyclodomorphus melanops	2.63	0.09			0.15	0.60		
	Egernia formosa				4.00				
	Lerista muelleri	0.20		2.33		0.30	0.27	1.12	
	Lerista verhmens	0.40		3.49	4.00	0.75	0.63	2.25	
	Lerista zietzi	0.81	0.12			0.30	0.03		
	Menetia greyii	2.02	0.09	1.16	8.00	0.75	1.07	2.25	
	Morethia ruficauda	0.81	0.16				0.05		
	Notoscincus butleri						0.25		
	Proablepharus reginae					0.30	0.22		
	Tiliqua multifasciata	0.20				0.90	1.04		
	# Individuals	245	193	30	13	328	1696	52	2557
	# Species	15	10	8	4	14	20	6	21
Typhlopidae	*Ramphotyphlops ammodytes*						0.08		
	Ramphotyphlops grypus	1.21	0.06	6.98		0.60	0.63		
	Ramphotyphlops pilbarensis		0.03			0.15	0.11		
	# Individuals	6	3	6	0	5	30	0	50
	# Species	1	2	1	0	2	3	0	3
Varanidae	*Varanus acanthurus*	5.67		6.98	12.00	3.29	0.88	1.12	
	Varanus brevicauda	0.40	0.06			7.32	7.15		
	Varanus bushi	0.40		2.33		0.60	0.33		
	Varanus eremius	0.81	0.03	2.33		1.35	3.21		
	Varanus panoptes	0.40	0.09	1.16		0.45	0.33		
	Varanus sp.	0.20				0.15	0.14		
	Varanus tristis	0.20		1.16		0.15	0.05		
	# Individuals	40	6	12	3	89	441	1	592
	# Species	7	3	5	1	7	7	1	7
	Total # individuals	494	321	86	25	669	3648	89	5332

the traps to avoid immediate recapture. A few individuals were vouchered with the Western Australian Museum or died in traps and were therefore not available for recapture. The trapping effort at each site was identical for the March and November surveys, making a direct comparison among sites and between surveys possible. Only reptiles and mammals caught in traps were used in this analysis.

Data analysis

Differences between data sets were compared using a *t*-test or an ANOVA when the variances were not equal and a hierarchical cluster analysis was undertaken in StatistiXL (http://www.statistiXL.com) using the Bray-Curtis dissimilarity coefficient with group-average linking for the combined March and November data to establish associations between site substrate and vegetation characteristics and trapped fauna assemblages. Cluster analysis was also used to generate separate dendrograms for the March and November data to demonstrate seasonal variations in the clustering of fauna assemblages. How and Cooper (2002) and How and Dell (2004) used NTSYSpc's (2000) Bray-Curtis dissimilarity index using the UPGMA method to group habitats based on the fauna assemblage composition.

The dendrogram from the cluster analysis showed various levels for grouping of survey sites based on the trapped fauna. To establish broad patterns of similarity among sites clustered in the dendrogram, we examined the substrate and vegetation at all sites looking for similarities and differences. Habitat variables considered were those that could be observed, such as vegetation type and structure, slope and surface substrate texture (*e.g.* loose stones, gravel, clay). We moved down the dendrogram to where similarities and difference in the substrate and vegetation among grouped sites could still be recognised and described. We used this grouping of sites as our fauna habitats.

Results

Fauna assemblage

A total of 5,332 individuals from 78 species were caught during the two surveys (Table 1). This included 912 mammals, 210 snakes and 4,210 lizards. On advice from the WA Museum, *Planigale* species could not be identified in the field (R. How pers. comm.) and as the only obvious difference among individuals was body size and we were unable to distinguish between juveniles and adults of different species, all individuals were grouped. It is possible that a few *Pseudomys chapmani* were misidentified as *P. hermannsburgensis*. Cooper (1993) indicated that differences in the size of the post hallucal pads on the pes of *P. hermannsburgensis* and *P. chapmani* can be used to differentiate these species. We found this diagnostic tool too difficult to use in the field and it is interesting to note that Cooper (1993) commented that a 10x hand lens should be used in identifying *Pseudomys* spp. from foot pads as pads are difficult to distinguish with the naked eye. We found no Pebble-mound Mouse mounds near our survey sites, so the number of individuals likely to have been misidentified would have been very low, if any. Five small varanids that were morphologically different to others in their size range and caught during the March survey were not able to be identified; these were recorded as *Varanus* sp. Photographs of these individuals were shown to a number of suitably experienced people including museum staff who were unable to identify them.

The mean number of individuals and species caught in each family at each site for the two survey periods is shown in Table 2. Skinks were the most frequently caught family, followed by geckos and varanids, and the least frequently caught were pythons and blind snakes.

Seven clusters of survey sites were recognised as fauna habitat types (Figure 5). Three of the clusters were single sites (C, D and G) and most sites fell into cluster F. Habitat characteristics for the seven recognised clusters are shown in Table 3. Cluster G was the most dissimilar, with the highest number of *Carlia munda* and *Amphibolorus longirostris* being caught at this location compared with all other sites. The major fauna attribute that differentiated cluster C from the other sites was the high number of *Planigale* species that were caught, and cluster D differed from other sites in that it had the least number of individuals (25) and species (13) caught at that site (Table 1).

A comparison between the dendrograms of survey sites for the March and November data sets shows little similarity (Figure 6), indicating appreciable differences in the vertebrate assemblages caught during these two survey periods.

Temporal differences

A total of 5,332 mammals and reptiles were caught during March and November, with more ($F_{1,106}$ = 129.4, P < 0.01) individuals being caught per site in March (mean 68.7 per site) than in November (mean 30.1 per site; Table 2). Also, more ($F_{1,106}$ = 69.6, P < 0.01) species were caught per site in March (19.3) than in November (13.5), with the combined survey period mean of 24.5 species per site. The total number of species caught in November (69) was higher than in March (66), and both were less than the total number of species caught for the combined data for both surveys (78). There was a significant difference

Table 2

Total number of individuals and species by family for the March and November surveys.

	Number of individuals			Number of species		
	March	November	Total	March	November	Total
Dasyuridae	224	158	382	4	5	5
Muridae	311	219	530	4	4	4
Agamidae	280	77	357	4	4	4
Boidae	28	4	32	1	2	2
Elapidae	104	24	128	9	8	10
Gekkonidae	434	197	631	11	14	16
Pygopodidae	42	31	73	5	6	6
Scincidae	1814	743	2557	18	19	21
Typhlopidae	33	17	50	3	2	3
Varanidae	438	154	592	7	5	7
Total	3708	1624	5332	66	69	78

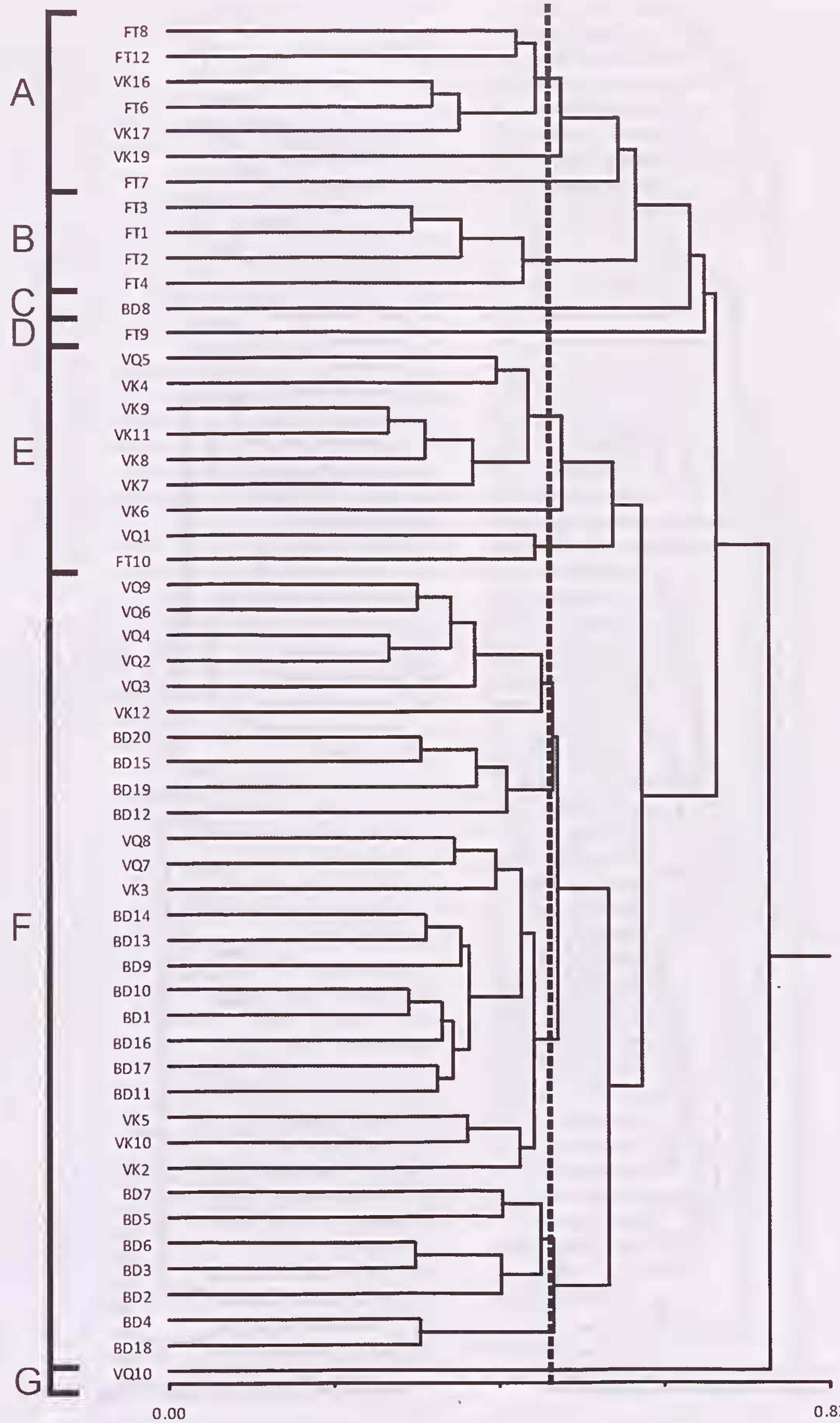

Figure 5. Dendrogram from a hierarchical cluster analysis of the fauna caught at 54 sites surveyed in March and November 2008 in the Hamersley Range with the level used to interpret seven clusters shown (dotted line).

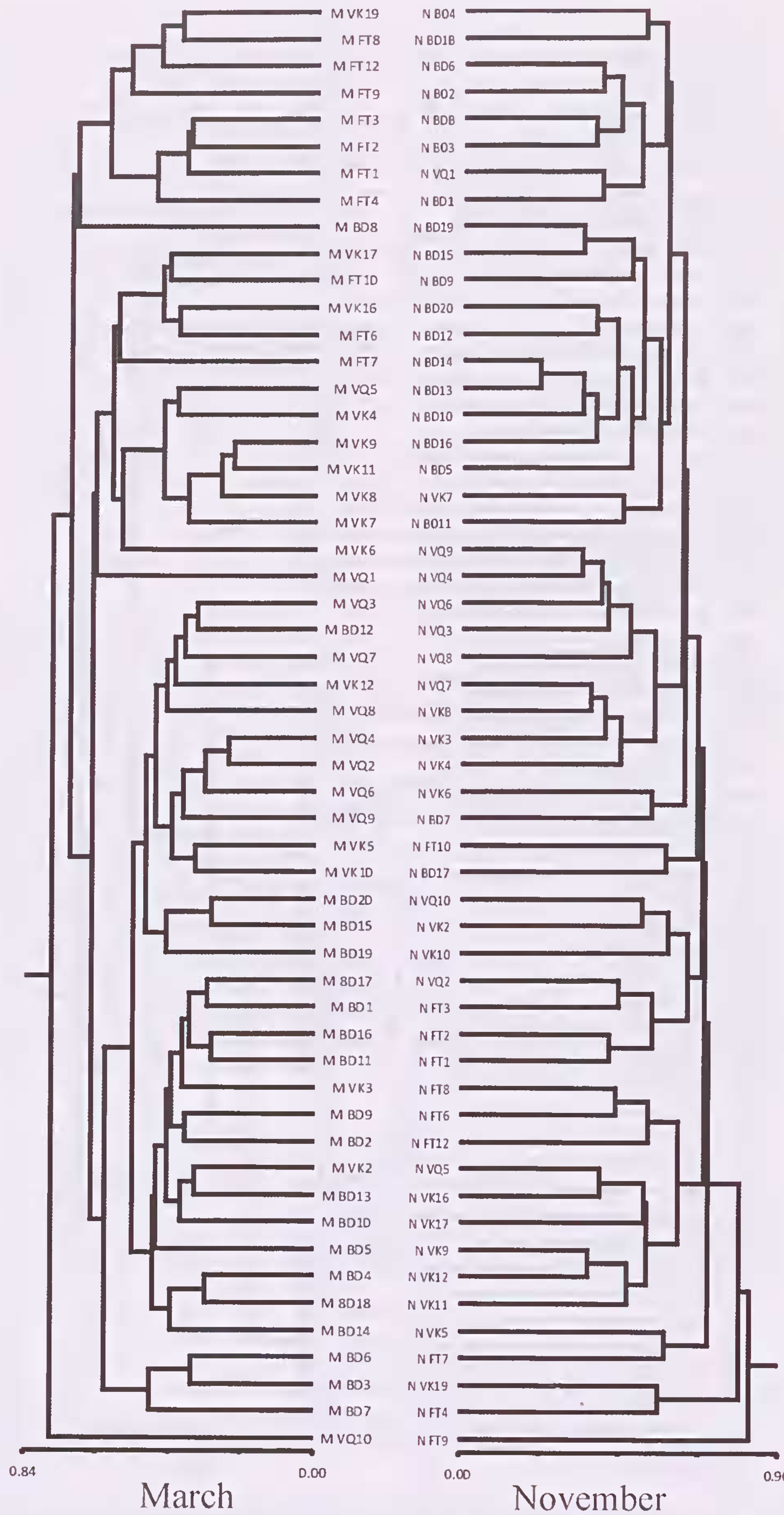

Figure 6. Comparison of the cluster analysis dendrograms for 54 sites surveyed in March and November 2008 in the Hamersley Range.

Table 3

Habitat descriptions for the clustered fauna survey sites as labelled in Figure 5.

Cluster	Habitat description
A	Sloping rocky terrain with low spinifex and scattered trees.
B	Gorge floor with a gravelly substrate that supported mature spinifex and shrubs to about 3m.
C	Flat area with mature spinifex on a clay substrate with lots of surface stones.
D	Steep rocky slope with low spinifex and lots of small stones on the surface.
E	Flat area with a clay substrate and lots of surface stones/rocks supporting scattered shrubs and small trees over spinifex.
F	Flat or gently undulating spinifex meadow with scattered shrubs and small trees with few surface rocks and stones.
G	Creek line with flowing water that comes to the surface in many places that supports tall eucalypts and melaleucas, shrubs and grasses adjacent to the water course on a creek bed of loose gravel or clay substrate.

(χ^2_9 = 90.8, P < 0.01) in the number of individuals caught in the various families between March and November, but no difference (χ^2_9 = 1.46, P = 0.99) in the number of species that were caught. We recorded 134 hatchling/ juvenile reptiles in March and 14 in November.

Discussion

The How and Dell (2004) data for the Abydos Plain sites incorporates individuals observed, so for comparative purposes we record the four additional species seen in the area but not trapped: *Aspidites melanocephalus, Liasis olivaceus barroni, Varanus pilbarensis* and *Varanus giganteus. Diporiphora valens, Caimanops amphiboluroides, Ctenophorus nuchalis, C. schomburkii, C. rubicundus, C. piankai, Diporiphora winneckei, Eremiascincus fasciolatus/richardsonii, Menetia surda, Lygisaurus foliorum* (*Carlia munda*?), *Nephrurus levis, Strophurus ciliaris, Heteronotia spelea, Acanthophis wellsi, Suta punctata, Ramphotyphlops waitii* and *Lerista frosti* (*L. jacksoni*?) have also been reported in the Hamersley Range by other authors (Texasgulf 1979; Johnstone 1980; Ninox Wildlife Consulting 1992; Biota 2008) but were not caught during our survey. The Hamersley Range therefore supports a diverse reptile fauna assemblage. By comparison, Thompson *et al.* (2003) reported large bioregional scale surveys in the Carnarvon Basin and Lake Eyre south catchment area recorded 76 and 57 species of reptiles respectively, and more localised surveys in or near the Great Victoria Desert (Red Sands), Uluru, Ewaninga, Simpson Desert, Great Victoria Desert (L Area), Bungalbin, Bold Park, Roxby Downs, Tanami Desert, Central Wheatbelt, Ora Banda and the Tanami Desert recorded 68, 37, 45, 36, 42, 46, 26, 27, 40, 42, 50 and 32 species of reptiles respectively. In addition to the nine species of mammals that we caught during the two survey periods, *Pseudantechinus* sp., *Pseudomys chapmani, Pseudantechinus macdonnellensis* (*roryi/woolleyae*?), *Sminthopsis ooldea* and *Tachyglossus aculeatus* have also been recorded in the area (Texasgulf 1979; Dunlop & Sawle 1980; Ninox Wildlife Consulting 1992; Biota 2008). The Hamersley Range includes flat plains, undulating hills, deep steep-sided gorges and valley floors, with substrates of sand, clay or rock, stony outcrops, breakaways and water courses that often support more dense vegetation. Vegetation is variable from large areas on stony substrate with little plant growth, to dense spinifex meadows or scattered and densely clumped shrubs and trees, so it is not surprising that the Hamersley Range supports high vertebrate species diversity.

Estimates of species richness based on trapping data are significantly affected by the trapping effort (Thompson & Thompson 2007). So when the trapping effort varies, as it does between our survey and the How and Cooper (2002) and How and Dell (2004) surveys of the Abydos Plain, the lower survey effort on the Abydos Plain is likely to have recorded a lower proportion of the species in the area. A species accumulation curve calculated using the methodology outlined in Thompson and Thompson (2007) for the combined data for our Hamersley Range sites indicated that we had caught 78 of a possible 83 trappable species (Figure 7). Above we indicated four other species that are known in the area that could have been trapped. How and Dell (2004) reported that there were 15 species of snakes and 51 species of lizards in the Abydos Plain area which compares with 17 species of snakes and 57 species of lizards that we either caught or observed opportunistically in the Hamersley Range. Opportunistic observation is not a reliable method for detecting some species, particularly geckos, but it was not possible to separate trapped and opportunistically recorded species in the How and Dell (2004) data, so we have included species observed but not trapped in our list to provide a comparison among fauna assemblages. How and Cooper (2002) caught nine species of dasyurids and five murids in their Abydos Plain survey compared with five dasyurids and four murids that we caught in the Hamersley Range. However, How and Cooper (2002) caught less than three individuals for seven of the dasyurids, with only two dasyurids (*Ningaui timealeyi* and *Dasykaluta rosamondae*) and two murids (*Mus musculus* and *Pseudomys hermannsburgensis*) relatively abundant. Of interest, Gibson and McKenzie (2009)

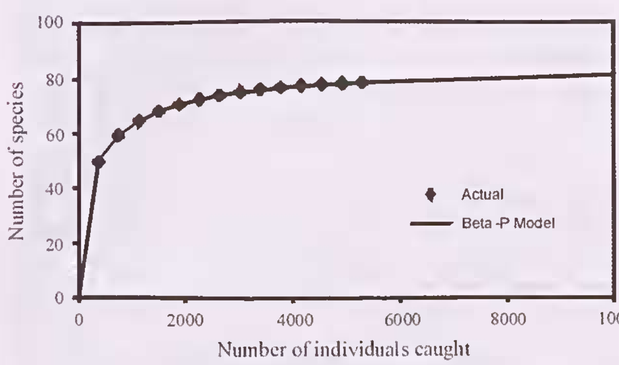

Figure 7. Species accumulation curve for all trapped vertebrate fauna for the March and November surveys

trapped 18 species of mammals with a body mass less than 50 g in the Pilbara biogeographic region. Gibson and McKenzie (2009) caught 3.5 individuals and 3.4 (± 0.1) small mammal species at each site. This is less than the 16.9 (± 2.30) individuals and 4.09 (± 0.56) species of mammals caught during our survey. Much of this difference can be attributed to the Gibson and McKenzie (2009) survey only using 125 mm PVC pipes as pit traps and a total of 140 trap nights at each site compared with a wider range of trap types and a higher survey effort in the Hamersley Range survey.

In summary, it is apparent that the high reptile diversity we report for a small section of the Hamersley Range is also present on the Abydos Plain. Mammal diversity in the Hamersley Range and the Abydos Plain were similar to that recorded in surveys in other areas in Western Australia (Thompson & Thompson 2008; Start *et al.* 2008).

Spatial variations

Based on our observations of the similarities and differences among clustered survey sites, we concluded that fauna assemblages in the Hamersley Range could be differentiated based on the slope of the terrain, substrate characteristics and the vegetation communities. Within the cluster of groups A, B, C and D, fauna on a steep rocky slope (*i.e.* cluster D) differed from that in cluster A (sloping rocky terrain), which differed from cluster B (*i.e.* gorge floor with gravelly substrate) and cluster C (*i.e.* flat with surface stones). The least number of species and individuals (*i.e.* 13 and 25 respectively) were caught on the steepest sloping survey site (*i.e.* Group D). The fauna assemblages in creek lines (*i.e.* groups G and B) differed from those in other areas. The fauna assemblage in a creek line that had flowing water either above or just below the surface and that supported melaleucas, taller eucalypts, dense shrubs and grasses (*e.g.* cluster G) was different from that in ephemeral creek lines that have a substrate of washed small gravel (*e.g.* cluster B). Fauna assemblages for sites grouped as E and F were on flat or gently undulating terrain, with the primary difference between the two groups being that cluster E sites contained lots of loose surface stones in contrast with cluster F sites that had few surface stones.

On the Abydos Plain the most dissimilar survey sites were those in riverine woodland along a creek line and the valley between steep slopes of calcrete mesas (How & Cooper 2002; How & Dell 2004). Small mammals showed well defined habitat associations, with *M. musculus* being mostly found in tussock grass banks of a creek, whereas *D. hallucatus*, *P. roryi*, *P. woolleyae* and *R. argurus* were found around granite tors, and *P. chapmani* were mostly found on rocky scree slopes (How & Cooper 2002). Gibson and McKenzie (2009) reported substrate characteristics (*i.e.* percent clay and silt, rockiness and ruggedness) were linked with small mammal species spatial distribution. They reported that *D. rosamondae*, *P. hermannsburgensis* and *Sminthopsis youngsoni* were more associated with sandy habitats, *D. rosamondae* avoided rugged areas and *P. hermannsburgensis* avoided rock outcrops. Gibson and McKenzie (2009) reported their *Planigale* sp. 2 was strongly associated with cracking and gilgaied clays, as was *S. macroura* but to a lesser extent as it was also found in a variety of habitat types. They suggested the two undescribed *Planigale* species in the Pilbara were separated on habitat type with *Planigale* sp. 2 preferring clay substrate and avoiding rocky habitat types and *Planigale* sp. 1 preferring the rugged substrate dominated by exposed bedrock. We only caught three of the larger *Planigale* sp., with two in cluster F (BD7 surface stones on a sandy-clay substrate vegetated with spinifex and scattered trees, VK5 surface stones on a sandy-clay substrate vegetated with spinifex and shrubs to about 2 m) and one in cluster A (VK17 stony slope with patches of spinifex and scattered trees). The smaller *Planigale* sp. was widely distributed. Gibson and McKenzie (2009) reported that *M. musculus* preferred the more fertile habitat such as those with a fine textured surface of loams and clays, but it was not strongly associated with any particular habitat in the Pilbara. Our data for the Hamersley Range recorded *M. musculus* in clusters E, F and G, which were flat or gently undulating plains with scattered small trees and shrubs over spinifex or the more densely vegetated creek line that had flowing water.

The reptile assemblage on the Abydos Plain was grouped based on those on deep loams with litter associated with fringing woodland vegetation along a creek line, those on a rocky breakaway and those on the deep sands of the Abydos Plain (How & Dell 2004). Some species that showed a strong preference for rocky habitats were infrequently captured on sandy substrates.

Digging in pit traps on rocky slopes (*e.g.* clusters A and D) in the Hamersley Range is logistically difficult, and it can also be difficult to do the same in creek beds (*e.g.* clusters B and G) that have dense vegetation and limited access. It is apparent that these habitat types support a different fauna assemblage to that which occurs in the adjacent areas. Often these assemblages will have fewer species and most often a subset of those in adjacent areas, so excluding these areas from a survey is unlikely to affect reported species richness for the entire survey area presuming sufficient survey effort has been deployed, but it will alter the understanding of the assemblage structure for the entire area.

Our observational data and records for other surveys in the Hamersley Range indicate that there are a couple of species that seem confined to habitats that are particularly difficult to trap (*e.g. V. pilbarensis, Oedura marmorata*), and others are in lower numbers (*A. melanocephalus, L. o. barroni*), or move infrequently and only small distances (*A. wellsi*) and can therefore easily go undetected.

Of particular interest was the *Nephrurus milii* that was caught in the floor of a steep-sided gorge that was a significant north-west range extension for this species (Thompson *et al.* 2009). This species is found in a variety of habitats elsewhere within its geographic distribution and is often abundant, but this was the first record for this species in the central and western end of the Hamersley Range.

Habitat generalists and specialists

Four species (*Dasykaluta rosamondae, Ctenotus isolepis, Diplodactylus conspicillatus, Lucasium stenodactylus*) were only found in clusters E and F, which are flat or undulating areas vegetated with scattered shrubs and small trees over spinifex. *M. musculus* was also only found in clusters E and F as well as cluster G, which is the creek line with flowing water that supports tall eucalypts and melaleucas, shrubs and grasses. *V. brevicauda* and *V. eremius* were mostly found on sandy loam substrates, but they were both often found in areas with a lot of surface stones. These habitats are appreciably different to the red sand ridge and swale systems of the inland deserts where *V. brevicauda* and *V. emerius* are abundant and wide-spread.

The most ubiquitous species in the Hamersley Range were *Heteronotia binoei*, *C. pantherinus* and *C. saxatilis*, all of which were caught at more than 51 of the 54 survey sites. The next most widely distributed species were *C. helenae*, *Planigale* spp., *Carlia munda*, *Pseudomys desertor*, *P. hermannsburgensis*, *C. grandis*, *V. brevicauda* and *C. duricola* which were trapped at more than 41 of the 54 survey sites. Other than *P. desertor* and *C. duricola*, all of these widely-abundant species were also caught on the Abydos Plain (How & Dell 2004) suggesting that they are relatively abundant in a range of habitat types in the Pilbara bioregion.

Assemblage structure

The Environmental Protection Authority's (EPA) Position Statement No 3 (2002) on terrestrial biological surveys indicated that best practice fauna assessments require the biodiversity of an area be evaluated at the ecosystem level. In the context of this statement and the rest of that document we interpret this to indicate that the EPA is seeking to identify and conserve fauna assemblages that are unique or have components that are of ecological significance (*e.g.* relatively high abundance of a particular conservation significant species or guild of species, or unusually high species richness or diversity). In order to make an assessment of a site or habitat type the fauna assemblage in the potential impact site should be compared with others within and beyond the bioregion to determine the extent to which it is unique and is of conservation significance. To date this is rarely done because there is limited comparative information available that enable a proponent to judge the conservation value of one fauna habitat against another within or beyond the bioregion, mostly because the sampling effort is either too low or so variable among surveys that comparative data among survey sites or fauna habitats are not available. Surveying 54 sites provided an opportunity to comment on what is a typical vertebrate fauna assemblage structure in the Hamersley Range.

The least trapped reptile families per site were pythons and blind snakes based on the number of individuals and number of species and the most abundant family was skinks (Table 2). Although not directly comparable because of different sampling efforts and protocols, these data are similar to that reported by Thompson *et al.* (2003) for numerous habitat types including sand ridges vegetated by spinifex, complex mosaic soils with mixed vegetation communities, and sand plains with shrubs and small trees. This pattern is also similar to that reported by How and Dell (2004) for the Abydos Plain.

The number of species and number of individual pythons and blind snakes caught was low, therefore it could be expected that the coefficient of variation

Table 4

Mean (± 1SE) and the coefficient of variation expressed as a percentage (CV%) for the number of individuals and species caught per family in each survey site (N = 54) for the combined data for both surveys.

	Number of individuals			Number of species		
	Mean	SE	CV%	Mean	SE	CV%
Dasyuridae	7.07	0.610	63.4	2.13	0.121	41.8
Muridae	9.81	1.022	76.6	1.96	0.099	37.0
Agamidae	6.61	0.721	80.1	2.11	0.126	43.0
Boidae	0.59	0.139	172.0	0.33	0.065	142.7
Elapidae	2.37	0.267	82.9	1.74	0.167	70.0
Gekkonidae	11.69	1.000	62.8	3.31	0.198	43.8
Pygopodidae	1.35	0.174	94.4	1.07	0.121	82.6
Scincidae	47.35	2.505	39.9	8.39	0.296	25.9
Typhlopidae	0.93	0.163	129.1	0.574	0.078	99.2
Varanidae	10.96	0.839	56.3	2.907	0.176	44.5

expressed as a percentage (CV%) for these species would be high (Table 4). The lowest CV% was for skinks, which was to be expected as a total of 2,557 individuals from 21 species were caught during both surveys and they were widespread and caught in relatively high numbers at most sites. However, an average of only 8.4 species of skinks were caught at each survey site from a maximum number of 21 skink species (*i.e.* 40%) caught at all sites, which is a similar proportion to that for dasyurids (43%), rodents (49%), dragon lizards (53%) and goannas (42%), but higher than that for pythons (17%), front-fanged snakes (17%), legless lizards (18%), geckos (19%) and blind snakes (19%). These data indicate that for a single site surveyed in the Hamersley Range, you are likely to catch a higher proportion of the dasyurid, rodent, dragon lizard and goanna species present in the area than you are for pythons, front-fanged snakes, legless lizards, geckos and blind snakes due to both a lower number of species and the capture rate of only a few individuals at each site. An average of only 3.3 of the 17 species of geckos were likely to be caught in any survey site, which suggests that this family contains more habitat specialists than, for example, skinks. However, this difference may also have been an artefact of the sampling with the more widely foraging skinks being caught more often than geckos which perhaps move more slowly and cover less ground and are therefore less likely to be trapped.

Over 50% of the total number of reptiles and mammals caught came from six and two species respectively. In contrast, 36 of the reptile species and five of the mammal species contributed less than 5% of the total number of individuals caught. This pattern of a high proportion of species being in very low abundance and a few species in high abundance is similar to that reported by How and Cooper (2002) and How and Dell (2004) for the Abydos Plain and elsewhere (Downey & Dickman 1993; Masters 1996; Smith *et al.* 1997; Gibson & McKenzie 2009). The implication from this for future fauna surveys in the Pilbara is that a large number of individuals need to be caught in order to record a high proportion of the trappable species in the area. This concurs with the analysis of Thompson *et al.* (2007) who used species accumulation curves for numerous fauna sites for various habitats within Western Australia to come to a similar conclusion.

What was unusual about the trapped fauna in our survey of the Hamersley Range was the high proportion of *V. brevicauda* (235), *V. eremius* (91) and *Antaresia stimsoni* (28) that were caught in the March survey. When the catch for these three species was expressed as a percentage of the total number of individual reptiles caught (7.4%, 2.9% and 0.9% respectively), this percentage is higher than the proportion of varanids and pythons reported for many of the 14 surveys in Australia compared by Thompson *et al.* (2003). The next highest values that we could find for varanids was 3.1% for *V. brevicauda* and 2.5% for *V. eremius* in the Simpson Desert (Downey & Dickman 1993), and 3.6% for *V. eremius* in habitat not recently burnt near Uluru (Masters 1996). Both of these habitats were very different to that surveyed in the Hamersley Range. These three species are carnivorous predators but feed on prey items of different size (Geer 1989, 1997). These data would suggest there is an abundance of prey items to support this relatively high abundance of carnivores. This conclusion is also supported by the unusually high number of *P. australis* that were trapped and seen spotlighting during the March survey period.

The high proportion of *Planigale* species (21.7% of all mammals caught) in the data set was of interest. How and Cooper (2002) only recorded a single *Planigale* sp. on the Abydos Plain and Gibson and McKenzie (2009) reported *Planigale* sp. 1 and sp. 2 represented 3.1% and 14.2% of all the small mammals they captured across the Pilbara. We probably caught at least two species of *Planigale*, with one being much larger than the other. Our inability to distinguish juveniles of the 'larger' species from adults of the 'smaller' species meant that we could not be sure how many of each species were caught, although we did record individual *Planigales* caught as either 'large' or 'small'. We only caught three of the 'larger' species and it did not appear as if they were found in habitat types different to that of the smaller individuals.

Temporal differences

Average maximum and minimum monthly temperatures and rainfall for Tom Price from 1987 to 2008 are shown in Figure 2. Average temperature differences between March (mean max. 33.8 °C and min. 20.6 °C) and November (mean max. 35.6 °C and min. 18.9 °C) are only a couple of degrees, with November typically having a higher maximum and lower minimum. For our survey, the pattern was the reverse with mean ambient maximum and minimum temperatures during the March survey (37.4 °C and 19.8 °C) higher than during the November (33.9 °C and 16.4 °C) survey.

The number of mammals caught in March was significantly higher than during November, indicating that the abundance of mammals was higher in March than in November as we used an identical trapping protocol. How and Cooper (2002) indicated that the dasyurids that were commonly caught on the Abydos Plain during their three year investigation showed little fluctuation in abundance when compared with the rodents. They indicated that the changes in dasyurid numbers were more readily explained by the introduction of juveniles into the population. However, for *Dasykaluta rosamondae* in the first two years (1988–1989), numbers were higher in September than in February or March, whereas in 1990 when their abundance was high, the reverse was the case. Dickman *et al.* (2001) reported that for dasyurids, abundance fluctuations in the Simpson Desert were related to interactions between rainfall, resource availability and predation, with variation much less than for rodents.

For some rodents and dasyurids (*M. musculus, Ningaui timealeyi, P. hermannsburgensis* and *Zyzomys argurus*), How and Cooper (2002) indicated that September 1989 represented the highest number of captures on the Abydos Plain which is the reverse of what we recorded. These authors attributed this to major rainfall events 18 and seven months earlier. Dickman *et al.* (1999) reported dramatic fluctuations in the abundance of rodents after significant rainfall at three sites in arid Australia. In their study *M. musculus* numbers increased after two months of exceptional rainfall, whereas the other species increased in abundance 3–10 months after rain. The rainfall pattern at Tom Price in the two years prior to our first survey indicated substantial rainfall between

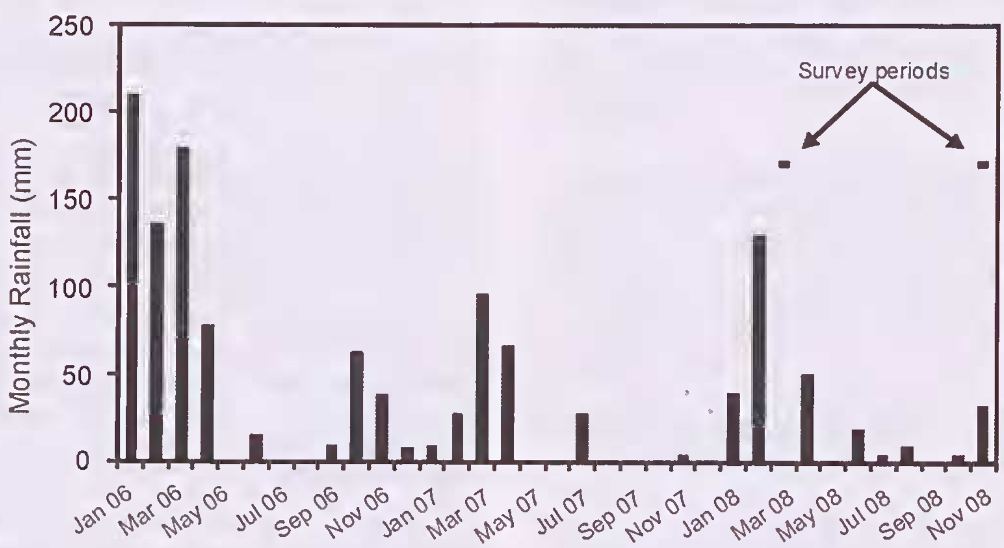

Figure 8. Monthly rainfall at Tom Price from January 2006 until December 2008.

January and April 2006, then a lesser amount in October/ November 2006 and March/April 2007, with almost no rain then until January/February 2008 (Figure 8). Rainfall in the summer of 2006/07 was below average. The rainfall pattern in this part of the Pilbara is largely determined by the number of cyclones that pass across the coast with the subsequent rain bearing low pressure systems providing much rain over a few days. The lower number of mammals caught in November compared to March may reflect the relatively dry winter of 2008 (Figure 7), the rainfall that occurred during the March survey or recruitment of juveniles from the spring-summer breeding in 2007. If a major rainfall event was the primary contributor to the higher number of mammals being caught in March, as suggested by Dickman *et al.* (1999), then many of the individuals that were present in March disappeared by the November survey. Rainfall occurred on days five (0.4mm) and nine (12.4mm) during the March survey and there was no obvious increase or decrease in the trap success rate before or after these events so we discarded rain during the survey as a major contributor to the higher catch of mammals in March. A reduction in dasyurid numbers due to the death of breeding males after mating (*i.e.* spring and early summer; Tyndale-Biscoe 2005) may account for a loss of some individuals and recruitment of juveniles into the population post breeding would probably offset this loss of males. If this were the case, then there would be a reduction in the population of dasyurids in early summer and an increase later in summer as the juveniles become independent of their mothers and actively forage for themselves. Many male dasyurids would probably have died by our November survey and juveniles would be present in the March survey. This might account for some of the variation in dasyurid numbers. It is our view that much of the variation in caught abundance reflected activity patterns which related to ambient nocturnal temperatures as the reduction in dasyurids and murids from March to November was similar.

The number of reptiles caught during March was appreciably higher than in November 2008. How and Dell (2004) reported significant temporal variations in trapping success of the lizard communities on the Abydos Plain, with the highest number of species and individuals being recorded in summer, and fewer species and individuals being caught in spring and far fewer in April, May and July. Fires also influenced the abundance of reptiles with burnt areas having both lower diversity and evenness. Thompson and Thompson (2005) reported highest species richness and abundance of captures for reptiles in January, followed by December and September and then April in the Goldfields of Western Australia. Almost no reptiles were caught in their June surveys, as was expected for these ectotherms. In contrast, Cowan and How (2004) reported only a modest difference in the number of reptiles caught between March and October 1979/80 (142 *vs* 172) and no difference between the same months when surveyed again in 2001/02 (116 *vs* 115) during a survey of the Goongarrie area which is about 70 km north of the survey sites used by Thompson and Thompson (2005). In the spinifex dune-swale system about 40 km south of Alice Springs in the Northern Territory, James (1994) reported some species were caught in higher abundance in spring (*e.g. Ctenophorus isolepis, Diplodactylus conspicillatus*), while other species were caught in higher numbers during autumn (*e.g. Rhynchoedura ornata*) and one species was relatively constant (*Ctenotus pantherinus*). James (1994) reported that over half the reptile species had greater than a two-fold variation in abundance during five consecutive surveys undertaken in spring of 1985, 1986 and 1987 and autumn of 1986 and 1987.

For the Hamersley Range survey reported here, 20 reptile species were only caught during one of the two survey periods. Many of these were singletons or doubletons (*e.g. Egernia formosa, Ctenotus rutilans, Delma tincta*), but 15 *Demansia rufescens* and 11 *Furina ornata* were caught in March and none were caught in November. Other species that showed enormous temporal variation included *Diplodactylus conspicillatus* (222 *vs* 8), *Amphibolurus longirostris* (80 *vs* 7), *Varanus panoptes* (21 *vs* 0), *Varanus brevicauda* (235 *vs* 79), *Tiliqua multifasciata* (41 *vs* 4), *Lerista verhmens* (33 *vs* 3), *Ctenotus saxatilis* (257 *vs* 70), *Ctenotus pantherinus* (315 *vs* 80), *Ctenotus helenae* (439 *vs* 157), *Ctenotus grandis* (226 *vs* 57), *Lucasium wombeyi* (47 *vs* 9) and *Antaresia stimsoni* (28 *vs* 2). In addition to the reported trapping program, we also undertook a spotlighting program in the evenings and recorded appreciably more *Pseudechis australis* (27 *vs* 0) and *Antaresia stimsoni* (35 *vs* 4) in March than in November. It rained on two occasions in March and not at all in November, which may have contributed to the higher number of *P. australis* and *A. stimsoni* being active at night (Cowan & How 2004). We suggest an important reason for the higher number of individuals being caught in March compared with November is the higher ambient temperatures recorded in March. Thompson and Thompson (2005) reported a higher number of individuals and species being caught in spring than autumn in the Goldfields and if this pattern prevailed in the Hamersley Range then more individuals and species would have been caught in November than in March. We could find no data to indicate that periods of light rain with the associated increased humidity in non-tropical habitats would significantly increase the catch rate for March compared with November; although we have unpublished data to show catch rates for many species decrease immediately after a heavy rainfall event in the Goldfields. On a seasonal basis, ambient temperature is known to significantly influence reptile catch rates. This affect might also be evident on a day-to-day basis. The recruitment of juveniles into the population after the normal late spring – summer breeding period (Greer 1989, 1997) could also contribute to a higher catch rate in March than November, presuming that many of the juveniles did not survive the autumn to be present in the subsequent spring. We are confident that the higher number of reptiles caught in March was not just due to recruitment because of the higher number of long-lived, relatively slow growing species caught in March such as *V. eremius, V. brevicauda, P. australis, T. multifasciata* and *A. stimsoni* that were not juveniles. However, many of the *V. panoptes* caught during March were juveniles, as it is difficult to catch the adults in funnel or pit-traps. These data provide a strong case for undertaking multi-season surveys to fully understand the fauna assemblage present.

To further illustrate the importance of multi-season surveys to fully appreciate the assemblage structure and relative abundance of the fauna, we visually compared dendrograms calculated using the same protocols from a cluster analysis of the March and November data. An inspection of Figure 6 indicates the grouping of survey sites based on vertebrate catches in March and November differ. We concluded from this that the composition of the fauna assemblages caught at the 54 sites in March and November differed. If an environmental assessment was based solely on the March data, then the extraordinarily high number of *V. brevicauda* (235), *V. eremius* (91), *P. australis* (18) and *A. stimsoni* (28) caught could suggest that some of these fauna assemblages were regionally unique as we could find no other example of such a high proportion of these carnivorous predators being present in a trapped population. However, if we look at the November data, the number of *V. brevicauda* (79), *V. eremius* (42), *P. australis* (1) and *A. stimsoni* (2) caught were about what would have been anticipated based on data from other surveys in the Hamersley Range (Texasgulf 1979; Johnstone 1980; Ninox Wildlife Consulting 1992; Biota 2008) and elsewhere in the semi-arid region of Western Australia. These data confirm earlier investigations which indicate that single season surveys do not adequately represent the fauna assemblage in the Pilbara (Cowan & How 2004; How & Cooper 2002) or other regions of WA (Thompson & Thompson 2005) and probably elsewhere in Australia.

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